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ABSTRACT

The purpose of this report is to provide reference material on the technical options for energy conservation in buildings. Actions pertinent to existing buildings and new buildings are considered separately. Regarding existing buildings, principal topics include summer cooling, winter heating, and other energy-related features such as insulation, fenestration, lighting, appliances, hot water, and human comfort. Suggested actions include those which can be accomplished voluntarily or without expense and those which require some modest effort or expense on the part of the building owner or occupant. Regarding new buildings, energy conservation actions that deal with building design and mechanical systems are described. The report concludes with a summary of mechanisms for implementation of conservation methods and criteria for use in evaluation of them. Throughout the report, emphasis is placed on technical options. The economic implications of such options have not been detailed. (Author/MLF)

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NBS TECHNICAL NOTE 789

Technical Options For Energy Conservation In Buildings

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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Technical Options For Energy Conservation In Buildings

National Conference of States on
Building Codes and Standards

and

National Bureau of Standards
Joint Emergency Workshop on
Energy Conservation in Buildings

Held at the

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Prepared by

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National Bureau of Standards
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FOREWORD

In late May 1973, the Office of Building Standards and Codes Services of the Center for Building Technology, National Bureau of Standards was approached by the National Conference of States on Building Codes and Standards with a request that the Bureau assist the States in preparing a workshop in energy conservation in buildings. Specifically, the Bureau was asked to identify measures that State officials could responsibly recommend to their Governors, many of whom had initiated conservation actions in anticipation of an energy crisis they felt to be imminent. The workshop was held on June 19, 1973; the material reproduced in this Technical Note was among the items distributed at the workshop to State, local and Federal Government officials as well as industry representatives and members of the press.

The staff of the Building Environment Division of CBT was called upon to prepare this document under the pressure of this urgent deadline. They drew upon the expertise of Bureau staff members, on the technical literature and on contributions of many colleagues in industry and other agencies of government.

No technical effort undertaken in so short a time can be accomplished without raising some question of technical and economic controversy. This is particularly true in the present case in that scientifically valid answers have yet to be obtained for many of the facets of energy use and conservation in buildings. For example, the concept of human comfort is exceedingly difficult to deal with quantitatively.

Therefore, this document should be read by all with this understanding: the technical options presented herein should be considered as a basis of reference for considered professional judgment.

For those who need technical guidance now, it is hoped that this document will be of practical use.

James R. Wright, Director
Center for Building Technology
Institute for Applied Technology
National Bureau of Standards

CONTENTS

INTRODUCTION

The purpose of this report is to provide reference material on the technical options for energy conservation in buildings. It has become increasingly evident in recent months that available energy reserves may be inadequate to meet peak energy demands in the United States this summer and possibly over the next few years. Actions relating to energy conservation are needed which will impinge on two important aspects of this "energy crisis." These are a near-term shortage of fossil fuels, and the threat of brown-outs and blackouts resulting from excessive peak demands for electricity.

Principal uses of energy in the U. S. are indicated on Figure A.*1/ Automobiles account for 68% of the transportation sector or about 17% of total annual energy consumption. Widely publicized efforts are currently underway to reduce this level through reduction of the amount of traffic and maximum speeds of automobiles on the nation's highways. The industrial sector is the dominant user of fuel energy in the U. S., 41.2% of the total. Of this, nearly 40% is used for process steam and 28% is used as direct heat. It is not clear how much energy use could be reduced in this sector. However, if substantial savings in energy use can be achieved in the residential and commercial sector these actions could significantly reduce the impending shortages.

To determine how much impact energy conservation actions in buildings could have it is essential to understand patterns of energy use in buildings. Figure B 1/ shows the principal uses of energy in buildings. Note the dominant

*Numbers refer to references listed at end of text.

role of space heating, which occurs, of course, mostly in the winter months. Summer loads of residential and commercial buildings consist primarily of air conditioning -- an estimated 56% of the summer load for commercial buildings and 30% for homes and apartments. Therefore, these are the most logical targets for concerted energy saving efforts. Also, it is important to note the interdependence of these various types of load. As will be shown in some detail in subsequent sections of this report, actions in any one of these areas are likely to influence energy use in others and often beneficially.

An estimate of the potential energy savings achievable through actions in the residential and commercial sector is presented on Figure C. These potential savings are expressed as percentages of U. S. total annual energy use. For this estimate for existing buildings it is assumed that summer cooling and winter heating loads could be reduced 30% and 40%, respectively. In the absence of any other basis for estimating the extent to which such measures would be adopted and when, it has been assumed that just 10% of these savings would actually be achieved.

For new buildings a wider range of energy saving options is available. Again in the absence of data on public and industry response to such measures, it has been assumed for this estimate that just 10% of new buildings each year would be impacted to this extent.

In summary, it would appear that these potential savings in the residential and commercial sector may have the same order of magnitude as potential energy savings in the transportation sector.

The balance of this report presents the details of the technical options which give rise to these estimates.

Actions pertinent to existing and new buildings are considered separately. In each of the three major portions of the chapter dealing with existing buildings -- i.e., summer cooling, winter heating, and other energy conservation features -- actions which can be accomplished voluntarily or without expense are considered separately from actions which require some modest effort or expense on the part of the building occupant or owner. Throughout this report, emphasis has been placed on technical options. Economic implications of such options have not been detailed.

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BASIC PATTERN OF ENERGY USE

TRANSPORTATION	25.2%
INDUSTRIAL	41.2%
RESIDENTIAL & COMMERCIAL	33.6%
	100%

Figure A.

x

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OF THE 33.6% RESIDENTIAL & COMMERCIAL

by type of use . . . . .

SPACE HEATING	53
WATER HEATING	12
AIR CONDITIONING	8
REFRIGERATION	7
LIGHTING	5
OTHER ELECTRICAL	5
COOKING	4
CLOTHES DRYING	1
MISC.	5
	100%

Figure B.

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POTENTIAL ENERGY SAVINGS AS % OF TOTAL ANNUAL ENERGY USE through action in RESIDENTIAL & COMMERCIAL SECTORS

- **EXISTING BUILDINGS (SHORT TERM)** — 1% OF ANNUAL TOTAL

  ASSUMING .... SUMMER COOLING (30%)
  WINTER HEATING (40%)

  10% OF BUILDINGS AFFECTED

- **NEW BUILDING (AT END OF 10 YEARS)** — 3% OF ANNUAL TOTAL

  ASSUMING .... ON ORDER OF 40% SAVINGS IN NEW BUILDINGS

  10% OF NEW BUILDINGS AFFECTED /YEAR

Figure C.

Summer Cooling
Existing Buildings
With and Without Extra Cost

Opening Statement

Use of summer cooling systems provides a worthwhile investment both in dollars and in energy for improvement in working conditions and quality of life which is not subject to debate because of the current recognition of energy utilization concern. The need, however, is evident to reduce the energy consumption to provide summer cooling, by improving the energy performance of cooling systems, by reducing the loads imposed on cooling systems, and by conscientiously reassessing the levels of cooling needs. The total use of energy for cooling will continue to increase - our objective is to reduce the relative requirement for each essential cooling system, existing or new, in order that the service rendered by such systems will continue to serve people. Even though the energy used for residential and commercial summer cooling is less than 3 percent of the national annual total it is 42 percent of the summer total for these types of buildings, and it does represent an annual national energy expenditure of more than 1.5×10^{15} Btu* (in 1968 and increasing at 10 percent per year)[1/]. If it is assumed that wasteful cooling system practices can be improved by implementation of the techniques to the extent presented here, then it is reasonable to expect that the energy requirement can be reduced as much as 30 percent over present rates,

*Patterns of Energy Consumption in the United States.

in many cases without sacrificial reduction of needed performance. In many cases the actual performance of systems can be improved at the same time that both dollar cost and energy cost is lowered.

Some of the suggestions to be made in our presentation today can be implemented with little or no cost. Others would require investment of materials or equipment and labor. Not all of these modifications have had broad experience because traditionally buildings have been constructed with primary concern for first cost, and some of the devices may not have an early payback in dollars although they can be expected to accomplish the energy reduction tasks. It is our hope that the necessary field and laboratory work will be done to evaluate these suggestions and determine other means to conserve our valuable energy resources.

Many of the suggestions for reworking existing systems and designing new systems can best be utilized by considering the investigation of all elements. This integrated design can best be done by professional engineers, architects and designers.

Summer Cooling
Existing Buildings
No Extra Cost

o Reduce use of cooling systems

Turn off cooling systems not actually needed for people or essential processes. Many cooling systems either in total or in part provide cooling in spaces which do not need cooling. These could be eliminated with little or no sacrifice. Examples of these areas are entrances, halls, storerooms and other such spaces which people use either infrequently or for only short periods.

Turn off cooling systems at all times when spaces are unoccupied. Many spaces are unnecessarily cooled continuously throughout periods of non-occupancy, for example homes and apartments unoccupied all day, meeting rooms, auditoriums, etc. which are used only occasionally. If cooling cannot be turned off completely during periods of non-occupancy, set thermostats (and humidistats) at the highest setting on the controls.

Turn off cooling systems in parts of buildings not in use. To facilitate this many buildings could have the occupancy schedules arranged to group light load uses in one wing, or on one floor rather than scattered throughout the entire building.

The energy reduction to be obtained by turning off systems will, of course, be determined by the extent to which these steps apply to a particular building. It is estimated that, on the average, this could reduce energy usage by 5 to 10 percent.

o Raise thermostat and humidistat settings

Thermostat settings of 75°F or lower are not uncommon, in fact, may be prevalent, for summer cooling operation. In systems with humidity control space humidity of 50% is a customary design. Recent studies show that, with suitable clothing, temperatures approaching 80°F and humidities approaching 60% R.H. may be acceptable.

Raising thermostat settings to 80°F and humidistat settings to 60% R.H. could reduce energy demand by an estimated 15% compared with operation at 75°F and 50% R.H. (Note: In some reheat systems internal operating temperatures must also be raised, along with thermostat settings, to effect the desired energy savings.)

Many systems because of poor zoning, poor distribution, improper location of controls, or improper control function, may actually operate at temperatures below desired levels. Adjusting and balancing such systems will reduce the energy requirement to the extent that overcooling is eliminated.

Humidity controlling systems, particularly those which use reheat, present opportunity to reduce energy usage by raising the humidistat to the highest acceptable setting. These systems operate to control humidity by cooling the air to remove moisture, then reheating as necessary to maintain the desired room temperature. Most of these systems use "new" energy such as electricity, steam or hot water for the reheating operation.

Even systems which use "recovered" eat (normally discarded) will use less energy if the humidistat setting is set at the highest acceptable level.

o Reduce cooling loads

Turn off or reduce to the lowest acceptable level all lights and heat-releasing appliances. Lighting, particularly contributes heavily to the cooling load of offices and commercial buildings. Encourage use of high - efficiency lighting at the point of actual work and minimize excessive general lighting. Reducing internal lighting saves energy in two ways: (1) reduction of the energy to operate the light, and (2) reduction of the load on the cooling system because the light energy is no longer released into the space. In some of the commercial buildings, lighting loads may be 50% of the total load. In homes, lights and appliances (TV sets, fans) increase the cooling load and should be turned off when not actually needed. Optimize use of natural light.

Minimize use of major heat producing devices or appliances whenever possible during periods of operation of the cooling system, or at least during periods of peak load operation of the cooling system. Peak load power plant operation is usually much less efficient than normal load application.

Use stove and oven ventilation hoods - the cooling load of the makeup air required by the hoods will probably be less than the heat release of the cooking operation. Avoid excessive cooking during the hottest weather.

To accomodate the higher temperature settings, encourage use of informal lightweight clothing.

In homes, turn off furnace pilots during the cooling season when practical. It is recognized that the service system for turning on pilot lights for winter may be taxed after the first cold night.

Reduce excessive ventilation. Cut back forced ventilation to minimum acceptable levels and operate ventilation systems only when necessary. Minimize infiltration by keeping all doors and windows closed during operation of the cooling system. Leave storm doors and windows in place during the cooling season. Seal off or close all unused chimneys and other unneeded vents.

Minimize solar loads. Shade all windows exposed to direct sunlight. Use light colored or reflective shades. Close venetian blinds.

Utilize outdoor air for cooling whenever possible. In homes opening doors and windows and placing fans in selected locations to draw air through the building can provide interior comfort when the outdoor air is just a few degrees cooler than the desired indoor temperature. In apartments, office and commercial buildings use of outdoor air for successful comfort cooling is more difficult to accomplish because of the lack of through paths for the air, lack of screens, non-openable windows, etc. Normal air ducts generally do not move sufficient air for cooling unless the supply air is at least 15 degrees below desired indoor temperature.

o Maintain cooling systems and components in clean condition and in good working order

Keep cooling system components such as coils, blowers, and especially filters, clean. Maintain entire system in good condition. It is difficult to quantify the energy cost for allowing cooling systems to operate in poor mechanical conditions, It is reasonable to estimate that a general energy reduction of 10 percent could be realized if a cooling system is kept clean and in good operating condition compared to operating that same system with dirty heat transfer surfaces, dirty filters and improper mechanical conditions.

Summer Cooling
Existing Buildings
With Extra Cost

Suggestions in this section are those which can be implemented with investments of money, equipment and labor. Suggestions in the previous section which required little or no investment should also be considered in support of the suggestions in this section.

Implementation of some of these procedures can result in lower overall dollar costs and energy requirements for providing normal cooling services than many existing systems designed prior to recognition of the urgent need to conserve energy and those designed with only first costs in mind. It is also possible that implementation of some effective energy-saving systems may not provide early dollar payback. Detailed long-term or "life-cycle" energy and dollar cost analysis should be made for all major new or modified cooling systems.

o Reduce the cooling load.

Reduce heat transmission through the building exterior

(1) by adding or installing effective insulation [criteria for determining adequate insulation effectiveness will be discussed by others later in this presentation as will other features relating to basic design.] Many buildings have inadequate insulation and the various techniques for adding insulation should be investigated.

(2) by reducing glass area and by installing insulating glass (or storm) windows and doors. Replace high conductive window frames with those of lower conduction values.

(3) by installing exterior solar shading devices, such as awnings, wings, balconies, trees, etc, to shield windows and walls from direct solar heating. Paint exterior surfaces in light colors and install light colored roofing.

(4) by insulating and ventilating attics and roof crawl spaces to reduce top floor cooling load. Hot ceilings on top floors of buildings not only require more cooling because of the heat flow downward, they actually require lower air temperatures to compensate for the radiant heat emanating from the ceiling surface. In homes, even those with ceiling insulation, thermostat controlled attic ventilating fans will reduce the interior cooling load sufficiently to more than offset the energy required for fan operation. Such fans can also be used to provide cooling by outside air through the house at night if proper air flow dampers or other devices are installed.

Install additional zone controls to permit selective use of cooling systems in only those areas of a building actually in use at a given time. Such additional zoning control should provide means for turning off cooling in unused areas in addition to providing selected levels of control during occupancy periods.

Reduce lighting loads by installing more efficient lighting fixtures sized to meet task plane needs. Avoid excessive general lighting by deactivating certain fixtures, or installing lower wattage elements. Install ventilated or water cooled light fixtures to remove a major part of the cooling load from the lights by cooling means other than the space cooling system. Keep light fixtures clean to avoid need for extra fixtures.

Establish schedules and provide automatic means for turning off lights, ventilating fans and cooling systems to match actual demand needs. Scheduling of activities in buildings to use one wing or one floor during light occupancy can facilitate establishing an optimum building use pattern.

Install automatic pilots in all heat operated devices in the conditioned spaces, particularly furnaces, gas clothes dryers and even stoves in homes.

Reduce unnecessary ventilation by installing suitable interior air filtering (odor and particulate) devices to lower the need for outside air. Ventilation air loads are a major portion of most cooling systems. If ventilation cannot be reduced install heat recovery devices (such as thermal wheels, heat pipes, "run-around circuits," etc.) to salvage the cooling effect in the exhaust air.

Reduce infiltration by repairs to the building such as caulking windows, weatherstripping doors, sealing penetrations and points, installing revolving doors and automatic door closures, etc.

o Improve cooling system efficiency

Eliminate reheat systems (for humidity control) which require "new" heat for the reheat function - convert to heat recovery systems (commonly referred to as "run-around" or bootstrap systems) which utilize the heat rejected from the cooling system for reheat.

Install equipment when needed for replacement or new uses, which has optimum energy-use characteristics. For example cooling units can be obtained with a wide range of effectiveness. In selecting new equipment conduct "life-cycle" energy-use analysis to determine which system will require the least total energy use. Consider all possible combinations of equipment/ building characteristics, particularly those with heat recovery features.

Install short-term (one- or two-days) heat storage equipment where applicable. For example, some buildings require cooling during part of a day, and heating part of a day - a heat storage system will permit storing some of the heat normally rejected during cooling and make it available for heating use during the night.

In all buildings which have separate heating/cooling systems, install control means to assure that simultaneous operation is either eliminated or minimized. In many buildings overlap or duplication of heating/cooling system operation occurs without being detected. A detailed analysis of the building systems characteristics will identify the possible areas for improvement in this regard. In homes. an interlock which prevents operation of one system when the other is operating can be installed, if not already provided.

Install heat recovery devices for all elements of the cooling system where opportunity for essential energy reduction exists. For example, use rejected heat from electric generating engines or turbines, waste heat boilers, or incinerators to power heat operated cooling systems. Consider on-site generation of power to provide this source of energy for cooling. Burn solid waste as a source of low cost energy. Consider powering cooling systems by prime movers other than electric motors when such applications are feasible, such as areas where electric power supply is marginal for the summer demand. Modify mechanical cooling systems to operate at condensing temperatures which drop as a function of outdoor temperature rather than hold a constant pressure.

Insulate and seal all ducts in non-conditioned spaces. In homes, particularly, this accounts for large losses in both cooling and heating.

In building with central cooling systems consider the use of separate spot or zone cooling units for spaces which are used for occupancy when the majority of the building is unoccupied. For example, in homes with central cooling installing a small room cooler in the bedroom would permit turning off the large system during sleeping hours. Similarly, in commercial buildings those office or other spaces which operate around the clock can use unit cooling systems during those periods when the majority of the building is unoccupied and the main system can be turned off. Some hospitals have found it practical to furnish individual cooling units in patient rooms which are used only when and if the occupants wish to pay for the service.

Central cooling/heating systems in multi-family apartments and in some multi-occupancy office buildings in which the cost of providing these services is included in the rent do not offer the incentive or, in some cases, the physical means to the occupant to minimize the use of the services. The use of individual metered systems, billed to the occupant, offers the advantage of allowing the occupant to have heating or cooling as desired and inherently includes the cost incentive to minimize the use to actual needs. Installation of such metering should be considered in modification of existing buildings or in designs of new buildings.

Modify the building cooling system to use cool outside air in lieu of the powered cooling system whenever the conditions permit. Many cooling systems operate at low outdoor temperatures and could make use of the outdoor air if the system were so designed.

Implement effective maintenance/preventive maintenance schedules to keep all cooling system components and in optimum operating conditions. Such scheduled maintenance may not always represent an optimum cost feature but should assure optimum energy utilization.

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SUMMER COOLING

RESIDENTIAL AND COMMERCIAL COOLING ENERGY USAGE IS

- 1.5×10^{15} Btu ANNUALLY*
  (EQUIVALENT TO $.44 \times 10^{12}$ kwh)
- 3% OF ANNUAL NATIONAL TOTAL
- 42% OF SUMMER TOTAL

*1968, INCREASING 10% PER YEAR

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SUMMER COOLING

REDUCTION OF ENERGY USAGE FOR SUMMER COOLING OF EXISTING BUILDINGS

- WITH LITTLE OR NO EXTRA COST
- WITH MODERATE COST

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SUMMER COOLING

REDUCTION OF COOLING ENERGY USAGE WITHOUT EXTRA COST

- REDUCE USE OF COOLING SYSTEMS
- RAISE THERMOSTAT AND HUMIDISTAT SETTINGS
- REDUCE COOLING LOADS
- MAINTAIN COOLING SYSTEMS

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SUMMER COOLING

REDUCE USE OF COOLING SYSTEMS

- TURN OFF UNNEEDED SYSTEMS
- TURN OFF IN UNUSED SPACES

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SUMMER COOLING

RAISE THERMOSTAT AND HUMIDISTAT SETTINGS

- SET AT UPPER COMFORT LEVELS

80°F, 60% RH vs 75°F, 50% RH COULD LOWER ENERGY BY 15%

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SUMMER COOLING

REDUCE COOLING LOADS

- TURN OFF UNNEEDED LIGHTS
- USE IMPROVED LIGHTING PRACTICES
- MINIMIZE USE OF HEAT PRODUCING DEVICES
- USE STOVE/OVEN VENTILATION HOODS
- WEAR LIGHTWEIGHT CLOTHING
- REDUCE EXCESSIVE VENTILATION
- MINIMIZE SOLAR LOADS
- USE COOL OUTSIDE AIR FOR COOLING

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SUMMER COOLING

MAINTAIN COOLING SYSTEMS

- KEEP HEAT TRANSFER SURFACES CLEAN
- CLEAN OR REPLACE AIR FILTERS REGULARLY
- LUBRICATE AND SERVICE UNIT REGULARLY

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SUMMER COOLING

REDUCTION OF ENERGY USAGE WITH EXTRA COST

- REDUCE THE COOLING LOAD
- IMPROVE COOLING SYSTEM EFFICIENCY

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SUMMER COOLING

REDUCE THE COOLING LOAD

- INSULATE OR ADD INSULATION
- USE INSULATING GLASS
- INSTALL SOLAR SHADING
- INSULATE AND VENTILATE ATTICS
- INSTALL ZONE CONTROLS
- REDUCE LIGHTING LOADS
- INSTALL AUTOMATIC PILOTS
- REDUCE UNNEEDED VENTILATION
- REDUCE INFILTRATION

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SUMMER COOLING

IMPROVE COOLING SYSTEM EFFICIENCY

- ELIMINATE 'NEW ENERGY' REHEAT SYSTEMS
- INSTALL HIGH-EFFICIENCY REPLACEMENTS
- INSTALL SHORT-TERM HEAT STORAGE
- INSTALL INTERLOCKS BETWEEN HEATING AND COOLING
- INSTALL HEAT RECOVERING DEVICES
- INSULATE AND SEAL DUCTS
- USE 'SPOT' COOLING
- USE INDIVIDUAL METERED SYSTEMS
- USE COOL OUTSIDE AIR FOR COOLING
- ESTABLISH EFFECTIVE MAINTENANCE

WINTER HEATING
- Existing Buildings

Opening Statement

Winter heating systems are a necessity for human health and comfort. The current effort to reduce and conserve energy for heating does not and should not impact severely on this basic human need.

The need to reduce energy consumption for heating by eliminating waste of heating energy is evident and can be accomplished by reassessing our levels of heating needs. The total use of energy for heating will continue to increase so that our conservation objective is to reduce the relative requirements for essential heating systems that exist or are newly installed.

Energy used for heating buildings, residential and commercial, is about 18 percent of the national energy consumption and represents a expenditure of 10.9×10^{15} Btu annually (in 1968 and increasing at 4 percent per year).[1/] If wasteful heating practices can be improved as much as anticipated then it is reasonable to assume that the energy requirement can be reduced as much as 40 percent over present rates, in many cases without sacrificing a reduction of needed performance. Further, the heating system performance may be improved at the same time that both dollar cost and energy cost is lowered.

Some of the suggestions presented here can be implemented at little or no cost. Others would require application of materials, equipment and labor. Not all of these suggestions have been applied on a broad scale because buildings in the past have been designed and constructed with first cost as the primary ground rule. Some suggestions have an early payback and others may take longer but all are expected to save energy. We hope that necessary data will be gathered in the laboratory and in the field to evaluate suggestions made here and by others.

Many of the suggestions made for existing buildings could also apply to new buildings. When considering reworking of existing heating systems or installation of new systems the suggestions for both should be investigated. Such an integrated approach can be done by professional engineers, architects and designers.

Winter Heating

Existing Buildings

No Extra Cost

o Set your thermostat lower

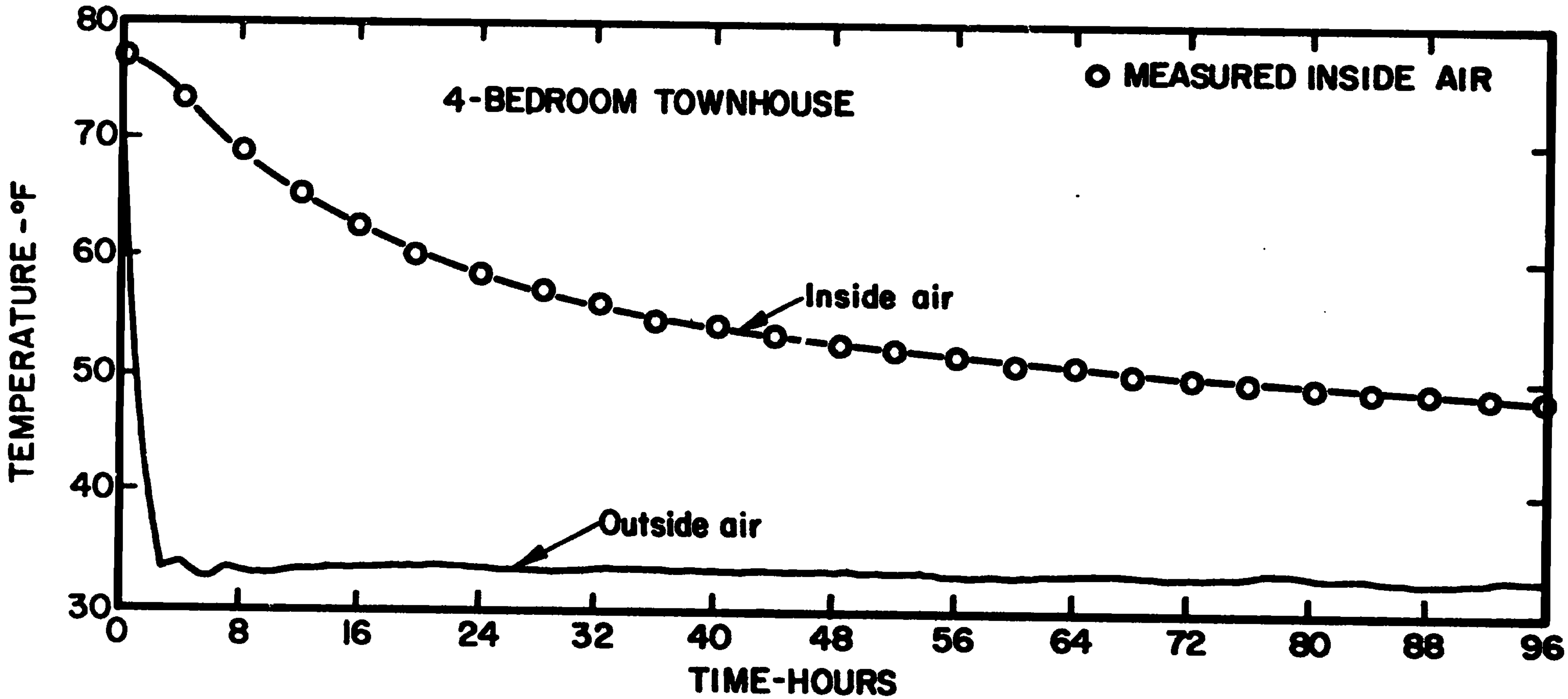
If you are now setting your thermostat at 76 or 80°F consider lowering the setting to 72 or 70 or 68°F and wearing more clothing. Roughly, for each degree above 70°F it will cost about 3% more for heating in a typical U. S. climate. This is true because the heating load is directly dependent upon the temperature difference between indoors and outdoors. The smaller you can make that difference the higher the percentage of savings.

Obviously, lowering the thermostat for long periods of time such as week-ends and vacations saves considerable heating energy.

Setting your thermostat lower overnight can save energy. It has been said that this is not worthwhile because the drop in temperature of the building and its furnishings overnight requires as much or more heating energy in the morning to restore comfortable conditions as can be saved. If energy is saved then how far back should the thermostat be set and for how long? As an example here are some results of an NBS-conducted laboratory test on a fully furnished 4-bedroom townhouse.

Figure 1 shows what happened to the temperature in this 60,000 pound insulated wood-frame house when the outdoor temperature was rapidly decreased to about 34°F and then held constant with no heating or lighting energy being supplied to the indoors. Note that in 8 hours the indoor temperature decreased from about 78°F to 69°F and it took about 24 hours to decrease to 58°F. These results are predictable by computer. Other tests, Figure 2, show that when the thermostat was lowered from about 75°F to 65°F for 8 hours at night a savings of 9% heating energy per day was observed for a night time temperature of about 3°F and about 12% for a night temperature of 21°F. Table 1 is computer calculated and shows the 24-hour percent fuel savings per day for 25 cities when the thermostat is lowered 5, 7 1/2 and 10°F at night for eight hours between 10 pm and 6 am. The table indicates that even though the percentage of fuel savings is higher in warmer climates the total savings will be greater in colder regions where more fuel is used.

In larger buildings energy can be saved by discontinuing humidity control at the end of the workday. It must be recognized that energy is required to produce water vapor to satisfy the humidity demand.



4-BEDROOM TOWNHOUSE
O MEASURED INSIDE AIR
Inside air
Outside air
TEMPERATURE - °F
80
70
60
50
40
30
0
8
16
24
32
40
48
56
64
72
80
88
96
TIME-HOURS

Figure 1

Center for Building Technology

4-BEDROOM TOWNHOUSE*

8-HOUR THERMOSTAT SETBACK	9°F	9°F
NIGHT OUTDOOR TEMPERATURE, MINIMUM	3°F	21°F
DAY OUTDOOR TEMPERATURE, MAXIMUM	35°F	65°F
24-HOUR HEATING ENERGY REDUCTION, PERCENT	9.0	11.5

* NBS MEASURED DATA

Figure 2

Table 1

Percent Fuel Savings* with
Night Thermostat Setback
From 75°F

Setback 8 hours; 10 pm to 6 am

City	5° Setback	7 1/2° Setback	10° Setback
Atlanta	11	13	15
Boston	7	9	11
Buffalo	6	8	10
Chicago	7	9	11
Cincinnati	8	10	12
Cleveland	8	10	12
Dallas	11	13	15
Denver	7	9	11
Des Moines	7	9	11
Detroit	7	9	11
Kansas City	8	10	12
Los Angeles	12	14	16
Louisville	9	11	13
Milwaukee	6	8	10
Minneapolis	8	10	12
New York City	8	10	12
Omaha	7	9	11
Philadelphia	8	10	12
Pittsburgh	7	9	11
Portland	9	11	13
Salt Lake City	7	9	11

Percent Fuel Savings* with
Night Thermostat Setback
From 75°F (cont'd)

City	5° Setback	7 1/2° Setback	10° Setback
San Francisco	10	12	14
St. Louis	8	10	12
Seattle	8	10	12
Washington, D.C.	9	11	13

*Minneapolis-Honeywell Data, 1973.

o <u>Close off rooms not used and turn off heat</u>

Closing off rooms and turning off the heat saves energy simply because the heating system need not supply that room. The amount saved would depend on the room size, weather and the time. Care should be used in cold climates to drain water from pipes or other containers that may freeze in the room or alternatively do not close off the room so tightly as to allow temperatures to go below 32°F.

o <u>On winter days let the sunshine in but pull the shades and drapes at night</u>

Solar heat can be used to help maintain room temperature. Any "green house effect" translates into energy savings because less heat is required from the heating plant.

At night when the window glass is chilled a closed blind or drapery reduces radiation heat loss from people near the window and may prevent them from feeling colder and turning up the thermostat. Closed blinds are usually not fitted tightly allowing room air to circulate through the space behind the blind and for this reason only a minor savings of fuel energy can be realized from blinds and drapes.

o <u>Reduce air leakage (drafts) and ventilation</u>

Warm air leaking from a building is replaced by cold air which must be heated. For many houses about 35% of the heating energy is used to warm the cold air which enters because of leakage. Therefore it is important for energy conservation to close and seal tightly openings from the indoors to the outdoors. Examples of air leakage openings include cracks around windows and doors, attic stairway doors, fireplace dampers when not in use, electric light ceiling fixtures, around plumbing vents or pipes, air ducts penetrating ceilings or walls, etc. A 1/4 inch crack 3 feet wide under an attic door could cost $5.00 a winter in energy waste. Simply placing a scrap piece of carpeting over the crack could stop this leak.

For larger buildings that have power ventilation systems reducing the amount of ventilation and size of fan motors, and operating by scheduling operations to use ventilation only where and when it is actually needed can save a considerable amount of energy, as much as 50% over inefficient operations. As an example see Figure 3.

o <u>Be careful about open windows and doors</u>

Open windows and doors represent a huge heating load. Cold air passing through a building will by-pass the insulating effect of walls, windows, doors, ceilings and floors causing the thermostat to start the heating plant which in turn tries

HEAT PUMP - VENTILATING AIR

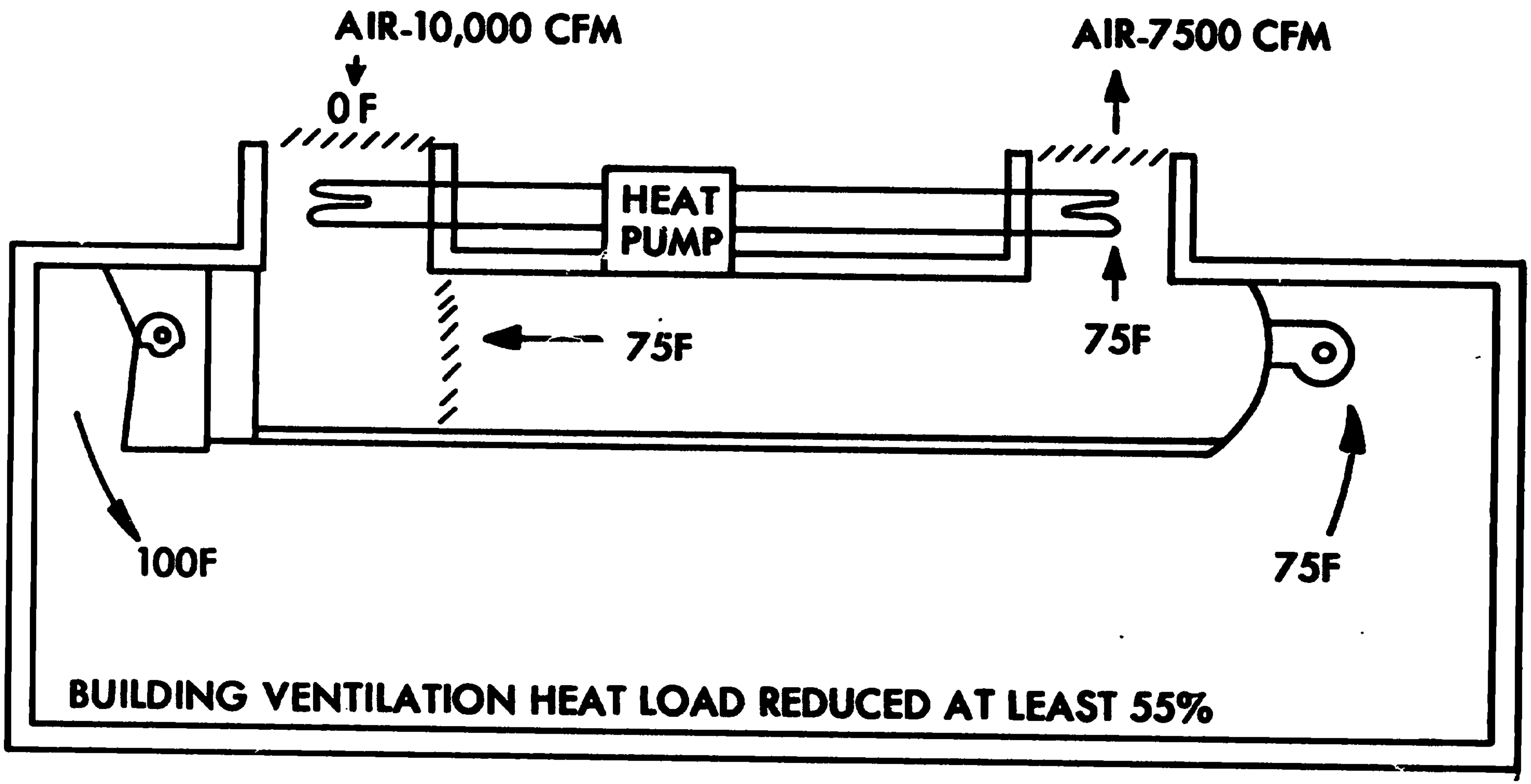


Figure 3

to heat a building that is being flushed with cold outdoor air. A simplified example of this is to open the bedroom window before retiring and not closing the bedroom door. The cold outdoor air finds it way to the thermostat while you are sleeping and the heating plant operates, sometimes fruitlessly, all night long wasting heating energy. For most situations a common sense approach should prevail. For example, standing in an open doorway talking with callers for long periods of time doesnt make energy conservation sense. Keep the conversation brief, send the caller on his way, or if prudent invite him in and close the door to keep the heat in. Also, as mothers know, children need to be constantly reminded to close the door behind them until it becomes an ingrained habit. Windows not normally opened should be latched to prevent or reduce constant air leakage through the cracks.

In large buildings where there is an almost constant stream of people entering and leaving the building use of such techniques as revolving doors, double sets of doors, and especially engineered heating and air systems can make a substantial impact on energy consumption for the building and should be encouraged.

o <u>Reduce the temperature in public spaces, corridors, hallways, lobbies, etc.</u>

Public spaces such as lobbies are not occupied by a given individual for a very long period of time. People usually move through these spaces, stand and talk for short periods of time but seldom sit for hours at a time. Reducing the controlled temperature even a few degress could save considerable energy in a given large building over a heating season. For employees that must spend their workday in these spaces selective heating of the actual work space could be provided and these employees could be encouraged to wear heavier clothing.

o <u>Institute rigorous schedules for planned operation of ventilation</u>

Ventilation systems in existing buildings are sometimes operated continuously and often without conscious planning to respond to the actual need. Operating ventilation systems only as needed in response to known building occupancy schedules could save energy. The ventilation required in modern buildings is variable with time of day and level of building occupancy. It is only partially predictable but the important point here is to first examine present scheduling with a view for changes that can be made to save energy without seriously influencing occupant comfort. Most ventilation systems can be adjusted.

Generally, the rate of ventilation to satisfy odor requirements changes in a ratio of 8 or 10 to 1 depending on whether the occupants are heavy smokers or non-smokers. Normal occupancy in an office building, for example, may occur for only about 10 hours per day and the use of toilets and cafeterias, where high levels of exhaust are needed, may be correspondingly less than 50 percent of this time as indicated in Figure 4. Some heating and ventilating systems are designed or can be operated for a high rate of ventilation with outdoor air during mild weather to control indoor conditions and a much lower level during the heating and cooling seasons.

A prominent mechanical engineering consultant from Chicago has estimated that 30 to 50% of the energy required for heating and 15 to 20% of the energy required for electrically powered air conditioning could be saved by variable exhaust of air and by utilizing heat recovery devices between exhaust and intake air. The design parameters are shown in Figure 5.

o Wear heavier clothing

Six key variables have been identified as having a major influence on human comfort in occupied building spaces. These are the temperature, relative humidity, air velocity, mean radiant temperature, the degree of physical activity and the amount of clothing worn. The occupant has a great deal of

Center for Building Technology

PLANNED VENTILATION OF OFFICE BUILDINGS

VENTILATION REQUIREMENTS

- 3 CFM/PERSON, OXYGEN SUPPLY
- 5 CFM/PERSON, ODOR CONTROL (NO SMOKING)
- 10-12 CFM/PERSON, CAFETERIAS
- 25-40 CFM/PERSON, SMOKERS

- 2 AIR CHANGES/HR, MIN., CORRIDORS
- 10-15 AIR CHANGES/HR, TOILET EXHAUST

OCCUPANCY AND USE

- 10-12 HR/DAY, OFFICES AND TOILETS
- 6-8 HR/DAY, CAFETERIAS

Figure 4

Center for Building Technology

DESIGN JUDGMENTS

- OCCUPANCY LEVEL
- AREAS OF HEAVY SMOKING
- DURATION OF DAILY USE
- USE OF MILD-WEATHER VENTILATION
- CONSTANT VS VARIABLE EXHAUST
- USE OF INLET-EXHAUST HEAT EXCHANGE

Figure 5

control over his own physical activity and clothing. Generally, bare arms and ankles tend to make a person feel cooler in heated spaces and simple compensation by wearing long sleeves, coats, sweaters and heavier and longer socks permit lowered room temperatures thus saving energy.

o Maintain an efficient heating plant

The operating efficiency of a heating plant is a very important factor in influencing the amount of fuel energy used for heating. For example, two prime sources of energy waste are the amount of air supplied for combustion and the conditions of the furnace or boiler. Heat trarsfer surfaces should be clean to minimize any reduction of heat transfer that may be caused from soot that results from products of combustion. The quantity of air received by the burner influences the efficiency of combustion. Too much air increases heat losses to the chimney and too little air does not allow complete combustion. Heating contractors or utility company personnel can check and adjust your furnace. Other things can be done effectively by building personnel. For example, air filters should be cleaned or changed and electric motors, pumps or other devices should be oiled or lubricated. A potential energy savings of 10% or more can be realized by maintaining the heating plant in good operating condition.

o Turn off - turn down lights and electric appliances except when needed

It is true that heat released from lighting fixtures and appliances in the winter contribute to maintaining indoor temperatures. The suggestion to turn off lights and appliances unless actually needed is made in the context of energy conservation. The rationale is that the thermal efficiency of electric energy supplied from the power plant is of the order of 30-35% and savings of electric energy at the point of consumption contribute directly and considerable to savings of fuel energy at the power plant. It has become customary to perform janitorial services in commercial and office buildings after the majority of the occupants leave in the evening. For operational and security reasons the lighting systems of these buildings remain on into the night while the work is being done. Frequently entire buildings remain lighted even though the work at a given moment is limited to one area. Using lighting only in areas of work and scheduling all work in one area at a time would permit significant reductions in the lighting energy. Consideration should be given to scheduling during daytime hours those janitorial tasks which will cause minimal interruption or interference to normal activity. This suggestion applies to all types of buildings year around.

o <u>Concentrate evening work or meetings in a single heating zone</u>

In large buildings instead of heating the whole building to accomodate a few people who must work in the evening consider asking the people to move for the evening to a heated zone in the building and then reduce the heating on the remainder of the building to save energy.

Winter Heating
Existing Buildings
With Extra Cost

o Add a clock thermostat

Night-time thermostat set-back can be done manually but in practice because of the necessity of actually turning it back it may not be done consistently. Automatic clock controlled devices to accomplish night set - back of the thermostat are available. Also, many buildings are presently equipped with clock-type thermostats that are not being used.

o Add insulation

The addition of thermal insulation to save energy has been verified many times. In existing housing, for example, adding insulation to the attic floor, about 6 inches deep, will contribute to comfort in both winter and summer and will pay for itself from savings from heating and cooling bills. Adding insulation to side-walls should be done with technical advice because of the possibility of moisture condensation within the walls.

Adding insulation to large existing buildings that are not insulated or contain minimum amounts of insulation may present practical and expensive difficulties because of such variables as the ratio of glass to insulated area, access to add insulation, interruption of personnel or vital services, and other considerations. Usually masonry buildings are difficult to retrofit with insulation. Therefore, professional advice should be sought before undertaking massive modifications because insulation is only one element which should be taken in context with other energy conservation techniques in large buildings.

The potential for energy conservation by using thermal insulation is large for all types of new buildings.

o <u>Add insulating glass or storm windows and doors</u>

Storm doors and windows and insulating glass save energy because they cut in half the heat that would be lost through the glass area of single pane windows. Generally, considering air leakage and conduction of heat through walls the net effect of heating bills could be a reduction of 10-15 percent. Further benefits in terms of comfort and a reduction of cold floor drafts are inherent. Also, storm windows and doors are effective in reducing heat gain in summer and thereby reducing the load on air conditioning equipment.

o <u>Caulk and seal around windows and doors, and other openings</u>

Caulking, sealing, and use of weatherstrip is very effective in sealing out the entry of cold air into a building and the exit of warm air from the building. Because of the necessity to heat cold air leakage about one-third of the output of the furnace is used for this purpose and any reduction air leakage will save energy.

o <u>Insulate heating ducts and seal against air leakage into non-heated spaces (attics, crawl spaces)</u>

Ducts that convey warm air from the furnace to the occupied spaces sometimes pass through unheated spaces such as attics and crawl spaces that are cold. Within these areas the ducts should be heavily insulated and sealed against leaking warm air to the cold space through cracks in the ductwork. When the furnace blower is working the duct work is operating under positive pressure. The air lost from these sections is a direct waste of energy.

In some buildings piping containing fluids such as water or steam will pass through cold spaces. These should also be heavily insulated to prevent gross heat energy loss.

o <u>Maintain heating equipment - clean heat transfer surfaces, change filters, set flames and combustion air</u>

This subject was mentioned under the heading of no cost suggestions. It is estimated that ten percent energy savings can be realized when comparing a well maintained heating system with a system that is not in good operating condition.

It is suggested that this work be done by service professionals.

o <u>Install heat recovery and conservation devices</u>

In buildings, especially large buildings, two prime areas of heating system loss are stack losses and ventilation air losses.

Recovery of some of the heat that normally would go up the stack and channeling it back into the heating system represents a means to conserve energy. Also, when warm air is exhausted from a building by a mechanical ventilation system and at the same time cool air is drawn in as fresh air, energy can be saved by removing heat from the exhausted air and using it to warm the cool air which otherwise must be heated by the normal heating system. Several techniques are available for accomplishing this energy savings. For example, to recover heat from stacks heat pipes, runaround circuts, automatic stack dampers, etc. and for ventilation systems runaround circuts, thermal wheels, heat pipes, heat pumps and other heat exchange circuts. The potential for ventilation heat load reduction is illustrated in Figure 6.

o Install automatic pilots

Energy can be saved if pilot lights on heating devices are replaced by substituting an automatic ignition device to light the burner. Gas pilot lights usually operate continuously 24 hours a day and typically consume 1 to 2 cubic feet of gas per hour. The fuel energy savings could amount to the pilot consumption when the burner is not operating. Replacing pilots could in some cases allow corrosion in furnaces or boilers and each system should be evaluated before extensive changes are made.

o Adjust ventilation systems

It may be possible to adjust ventilation systems in a way to cut down on the amount of air flow and maintain comfort conditions. Use of heat recovery devices and additions of odor removal filters could be studied as a means for maintaining comfort with less net energy consumption.

o Avoid use of portable electric heaters by improving main heating system

Electric energy could be conserved, with its attendent savings in fuel energy for power generation, if the use of portable electric heaters is avoided by improving the main heating system of the building.

Fuel fired heating plants in a building operate at thermal efficiencies of about 60-75 percent while the thermal efficiency of electric power generation is about 30 percent. The difference in efficiencies is indicative of the amount of energy saved.

o Replace defective or inefficient heating systems with systems of higher efficiency

Over the years improvements in heating systems have been made to make them more efficient. If present systems are defective and are known to be inefficient the difference in efficiency between an old and new system is a savings in fuel energy when both systems must accomodate the same load.

o Modify systems for zone control using systems of higher efficiency

In some larger buildings the heating requirements of different zones or areas in the building vary but the original heating system is designed to respond to a single control or thermostat. Those types of systems could be modified by the addition of control valves and the addition of thermostats that prevent overheating with its attendant waste of energy.

o Provide means to transfer heat from the core of a large building to the cool periphery needing heat

Heat generated by people and activities in the central core area of large buildings is often in excess of what is needed to provide heating needs. If this excess heat is ventilated to the outdoors or is absorbed by refrigeration systems at a time heat is supplied to the colder periphery changes could be considered to transfer this heat to where it is needed and when it is needed by modifying existing systems or their controls. The energy savings would amount to the equivalent of that energy that would have been rejected to the outdoors.

o Install automatic door closers

Open doors represent a major heat leak. People tend to leave doors open even in winter. Automatic door closers would save the energy that would normally be lost. The savings are difficult to quantify but it is estimated that it is worthwhile. Some data are available in the handbooks of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), New York, N. Y.

Center for Building Technology

WINTER HEATING

RESIDENTIAL AND COMMERCIAL SPACE HEATING ENERGY CONSUMPTION* IS

- 10.9×10^{15} BTU ANNUALLY
- 18 PERCENT OF ANNUAL NATIONAL TOTAL
- 1968, INCREASING 4 PERCENT PER YEAR
- WASTE IS 40 PERCENT

* 1968, PATTERNS OF ENERGY CONSUMPTION IN THE U.S.